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Developing Tangible Data Literacies for the Internet of Tangible Things

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Abstract

This paper poses the question how to design tangible interactions with the Internet of Things (IoT) in a way that supports people to develop better mental models of the underlying cyber-physical systems and thus enrich the ways that people engage with and create new knowledge from them.

Mental Models of the Internet of Things

As Internet of Things (IoT) technologies become more prolific and embedded into everyday life it is essential that the people using and interacting with these devices have the capability to understand and make the best use of them. However, human interactions with the Internet of Things (IoT) are hampered by lack of common understanding of such relatively new technologies and interaction paradigms.

In one example, Yarosh and Zave [4] looked at how people develop mental models around the types of conflicting rules that often need to be resolved to a single action within IoT systems. For example, determining whether a door should be automatically locked or unlocked, taking into account sensor information, prior programming and users activities (such as walking in and out of a house with shopping). Their studies revealed that people may bring bias when predicting two equally likely events (whether a door is



Figure 1: A sensed parking garage

locked or unlocked) based on a negative association with one outcome. They would also interpret events differently when they were initiated by a user or triggered by a sensor.

In another example, Clark et al. [3] found that there was no natural way in which users would conceptualise a smart home. Thus, in order for users to have adequate models of IoT and smart home technologies, they would first need priming. Similarly, the method of priming would affect the type of model built. In order to discover this they presented information to participants in two ways a) as a list of smart devices a user could configure within their home b) in terms of the data that would be made available (via devices/sensors) and the main properties and values. Their main finding was that richer mental models of IoT were developed by participants who were presented with the data. This was evidenced through a task where they would describe how they might configure smart systems in their home. For example, 'I would love to have a controllable TV' (device) or 'turn TV on. Lock all doors. Adjust temperature to 70 degrees Celsius'. (data). They conclude that designers within IoT need to consider this priming effect as part of their system design, in order to help users understand how the system will function and the kinds of interactions they can have with it.

To summarise, the above research raises the question of how to design interactions with IoT technologies that support users in developing better mental models of the underlying systems, thus improving their experience and use.

Internet of Tangible Things

The Internet of Tangible Things (IoTT) aims to improve the interactions that people have with IoT by providing more naturalistic and embedded interfaces. IoT technologies are derived from a natural and lived environment and many of the benefits are felt as people go about their daily lives. While the smart phone has played a major role in allowing people to interact with the internet anywhere at any time, it still offers only a screen-based, visual, interaction. This makes interactions with IoT technologies less embedded into daily life and leads to a disconnect from the environment from which such data is derived [1].

Whilst tangible interaction has the possibility for better connection of people to the IoT and the data it generates, it does not resolve the problem of how to support development of mental models. It is in fact possible that using new interaction paradigms will in some ways make this job harder, by removing some of the familiarity that people have from regular interfaces and the literacies they have developed for reading and reacting to information presented through such interfaces. Further, if the IoTT can begin to provide access to data in more tangible forms (and why not also auditory and olfactory?) then there is a real question as to how we can expect people to interpret this without prior instruction, similar to the instruction people get at school in how to read certain types of data visualization.

At the same time, whilst there is a strong history of research into design principles for standard visual interfaces such as reducing complexity, or building in adaptivity to provide additional interface functionality in

response to increased learning (e.g. see [2]), it is not clear how these would translate to tangible interfaces.

Therefore, it is necessary to develop new design principles for the IoTT to guide users in their use. Taking into account the findings of Clark et al. [3] such support might focus more on helping users to understand the data that drives the functionality and in understanding how they are interacting with this data, rather than how they are interacting with the tangible device.

Developing new tangible data literacies

The first half of this paper has raised some potentially interesting questions. Rather than offering solutions, the remainder of this paper will describe some past work that may be a starting point to help to inform how to bridge a gap between IoT, tangible interfaces and human understanding on a path towards developing new literacies for interacting with the IoTT.

Sensored parking garage

The sensed parking garage shown in Figure 1 was created to 'show' instead of 'tell' how sensors provided intelligence in a smart city, as part of a public engagement event at a museum. Museum visitors would interact with sensors by moving a car over a light sensor. This would show data on a nearby screen, counting how many people had driven into a parking bay over the course of the day and how many bays were currently occupied (as shown by a picture of a car with a light either on, or off, above it). The idea was that by seeing how data could be collected across a car park at a single point in time, or aggregated over time for a single bay, the young visitors would develop a better sense of the ways in which this collected data

could support both real-time parking support (how many empty bays there are) and also longer term planning (when are the peak times or days). This would improve their data literacy for using complex data from sensors to answer real world problems.

Conversations with young visitors revealed that from very minimal interactions they developed excellent mental models of the overall system. In this demonstration, their tangible interaction was through the toy car and the information was displayed on a separated screen. However, in the real world the car itself is the interaction device. What if the car, through voice or screen, also gave some feedback to visitors when it interacted with a sensor to tell them a little more about what was happening in the garage, or how busy the car park had been that day? Would this improve engagement with and understanding of the underlying system and lead to a better user experience?

Ideation through making

This activity, conducted on four separate days at the same museum, prompted visitors (mainly, but not uniquely, younger visitors) to design and make a light up badge that could act as an interface to data. The badge should have one or more LED lights that would respond to incoming data, for example pulsing in response to data arriving, using varying tempo to indicate time-series data arriving, or being in an on/off state depending on some state of a system. To support thinking about this, the visitors made the badges with flashing LEDs. The shape of the badge should also reflect its use.



Figure 2: A sensed tree

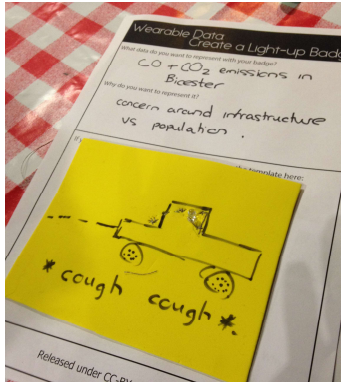


Figure 3: A sensed environment

The activity was designed to inform visitors about the smart city by encouraging them to invent novel applications. It followed a series of app design challenges with high school students in which they were prompted to ideate new smart technologies through sketching interfaces on paper [5]. However, in this case the interface was deliberately constrained to prompt deeper thought about the underlying sensors, data and the overall design rather than the more mundane aspect of an interface, such as a logo, or whether a user was logged in or not, which was a tendency across the app challenges and which detracted from thinking about the 'smart' aspects. Framing the challenge in this way led to very creative and 'personal' design. One example was a Christmas tree that had an LED on top. This would blink to alert the user that a sensor on the real tree had detected a new present appearing (Figure 2). Another example from an older visitor was a car that would alert to high CO and CO2 emissions (Figure 3).

Whilst not formally evaluated, an observation from across all of these making sessions were that younger visitors tended to design around direct interaction between a single sensor and the badge (as in the tree example), whereas older visitors were more likely to think about a sensed environment (the car). This is a potentially interesting clue about how mental models of IoT might develop at different ages and that younger users might need a different type of support.

Conclusions

This paper describes two activities designed to connect young people to IoT and data through tangible interactions. Whilst the focus of these activities was on using the tangible activities to support developing new

data literacies and better mental models of IoT, there is a possible starting point to think about how the findings could help inform the design of interfaces to the Internet of Tangible Things.

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